AD-A260 910

UMENTATION PAGE

Form Approved
OMB No. 0704-0188

(2)

ion is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, ... leting and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this ... ducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson ... and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
1-29-93	Annual Technical 2/1/92 - 1/31/93

4. TITLE AND SUBTITLE

Interferometric Measurement with Squeezed Light

5. FUNDING NUMBERS

N00014-92-J-1302

4124133-01

6. AUTHOR(S)

Prof. Hermann A. Haus

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Research Laboratory of Electronics
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Department of the Navy
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Work by Prof. Haus and his collaborators is summarized here

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Supplement to Annual Technical Report

Interferometeric Measurement with Squeezed Light

Period Covering: February 1, 1992 - January 31, 1993

On October 20, 1992, an Annual Report was sent covering the work to date. In the meantime, we have made further progress that should be reported before the ending of one year of the contract. Also, some publications acknowledging the ONR contract had not been included.

Phase Measurement Below the Shot Noise Level

As mentioned in the previously submitted report, we have succeeded in measuring the phase difference between the two arms of a linear Mach-Zehnder interferometer at a level 3 dB below the shot noise level, using squeezed vacuum injection into the "vacuum" port of the interferometer. The squeezed vacuum was obtained from a fiber ring reflector, in spite of the fact that the fiber had high Guided Acoustic Wave Brillouin Scattering (GAWBS). We employed a new modulation scheme proposed by Shirasaki and Haus[1]. The paper reporting these results has been accepted by, and will be published in, *Optics Letters.*

Pulsed Excitation of a Resonant Ring Gyro

We have been in close touch with Draper Laboratory researchers who are developing new fiber gyros. They have been supporting some of our work in the past. Particularly helpful has been the access to their fiber coupler fabrication and test facility.

For some time now, we have been searching for ways in which our squeezing effort would be utilized in their fiber gyros. Since most gyros are not limited by shot noise for the integration times usually employed, it was not clear when our work would be of use to them. Recently, Draper Laboratory interest has been greatly increased by the realization that their resonant ring fiber gyro would increase its signal to noise ratio if it employed pulsed excitation. Hence, our work is of relevance to them, not in producing squeezing, but rather in perfecting a technology for pulse-excited fiber gyros.

Squeezing with Short Pulses

The IBM group has pursued squeezing with short soliton pulses of increased peak intensity and with shorter fibers. This is done because the GAWBS is the less damaging the shorter the pulse and the shorter the fiber. They were successful in suppressing GAWBS, but found a noise floor which limited the squeezing to about 3dB. This noise floor is not fully understood. They have made computer simulations of the Raman noise and found that it should not have affected their results.

C. Doerr has reproduced these experiments in our laboratory, with essentially the same results. He also found a noise floor. This prompted us to look more carefully at the Raman noise. This noise has been extensively explored when Raman amplification was tested for long distance soliton propagation at the AT&T Bell Laboratories. Our investigation has shown that this theory is not adequate to explain the Raman noise associated with the self-frequency shift. In this case the slowly varying envelope approximation is not legitimate. We have developed a fully analytic theory of the noise, and our predictions show that the Raman noise could very well be responsible for the noise floor, preventing squeezing with pulses shorter than 500fs. We are in the process of developing experiments to test this theoretical result. If confirmed, we shall get in touch with the IBM group for a critical discussion of their results and ours.

Quantum Theory of Nonlinear Optics

The theory for the generation of squeezed light must be based on a selfconsistent quantum analysis of nonlinear optical phenomena. Current experiments can be explained if these nonlinear equations are linearized. Yet, the fully nonlinear analysis presents both a challenge, and an opportunity. The challenge comes from the fact that the instantaneous Kerr effect leads to singularities. Briefly stated, quantum noise occupies the full spectrum up to and beyond the vacuum UV. If the noise with its full spectrum interacts with a nonlinear medium, its effect becomes singular. In the literature, this singularity has been eliminated by noting that the Kerr medium has a finite cut-off frequency and this removes the singularity. We have shown that the limited bandwidth of the fiber mode spectrum leads to a non-delta function like commutator of the field operators and also removes the singularity.

As mentioned the selfconsistent nonlinear quantum analysis also presents opportunities. Every measurement of a physical variable employs a nonlinear device. The quantum theory of measurement is handicapped by the fact that it is difficult, in general, to quantize the measurement equipment. For some optical measurements this can now be done. Paradoxes that have been raised in the past about the interpretations of a quantum measurement can be resolved for some optical measurements. We have submitted for publication a paper addressing these fundamental issues.

Publications

1. H. A. Haus and F. X. Kärtner, "Quantization of the nonlinear Schrödinger equation," *Physical Review A* **46**, 1175-1176, 1 August 1992.

2. K. Bergman, H. A. Haus, and M. Shirasaki, "Analysis and measurement of GAWBS spectrum in a nonlinear fiber ring," *Applied Physics B* **55**, 242-249, September 1992.

3. C. R. Doerr, M. Shirasaki, and H. A. Haus, "Dispersion of pulsed squeezing for reduction of sensor nonlinearity," *Optics Letters* **17**, 1617-1619, 15 November 1992.

4. F. X. Kärtner and H. A. Haus, "Quantum nondemolition measurements and the 'collapse of the wave function,' submitted to *Physical Review A*.

5. K. Bergman, C. R. Doerr, H. A. Haus, and M. Shirasaki, "Sub-shot measurement with fiber-squeezed optical pulses," to be published in *Optics Letters*.

Office of Naval Research

DISTRIBUTION LIST

Herschel S. Pilloff Scientific Officer Code: 1112LO Office of Naval Research 800 North Quincy Street Arlington, VA 22217	3 copies
Administrative Contracting Officer E19-628 Massachusetts Institute of Technology Cambridge, MA 02139	1 copy
Director Naval Research Laboratory Washington, DC 20375 Attn: Code 2627	1 copy
Defense Technical Information Center Bldg. 5, Cameron Station Alexandria, VA 22314	2 copies